First CDF II Top Results

Patrizia Azzi - INFN PD

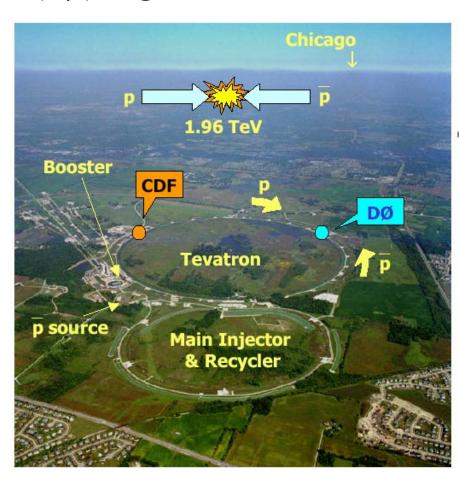
Tevatron Status

CDFII Upgrade Performances

Top Cross Section

Top Mass

Prospects for RunII

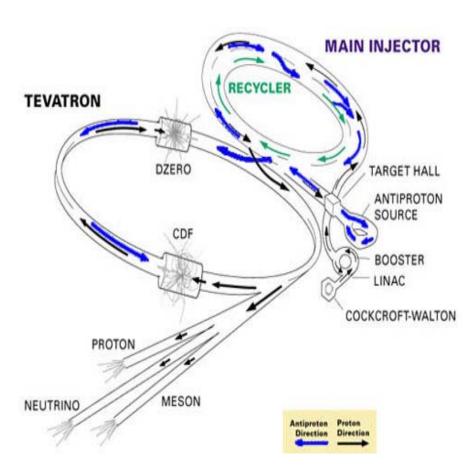


Accelerator Changes Run I -> Run II





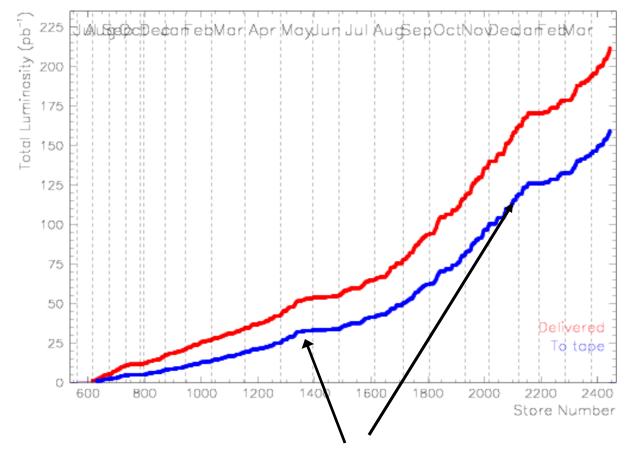
- Main Injector (150 geV proton storage ring) replaces Main Ring
- New permanent magnet storage ring for pbar accumulation (Recycler)
- O Higher energy collision:
 900 →980 GeV/beam
- Increased number of p and pbar bunches: 6→36
 - 396 ns beam crossing time
- Increased luminosity:
 - Run I max 2×10^{31} cm⁻² s⁻¹
 - Run II max $2-4 \times 10^{32}$ cm⁻² s⁻¹



Run II Data Taking Status







- ~220 pb⁻¹ delivered by the Tevatron
- \odot ~150 pb⁻¹ on tape
- ~100 pb⁻¹ will be used for Summer Results
- Detectors are integrated
- ⊙ ~5-7pb⁻¹/wk @90% efficiency

Shutdowns June 2002 and January 2003

Analyses for today: 57.5-72 pb⁻¹

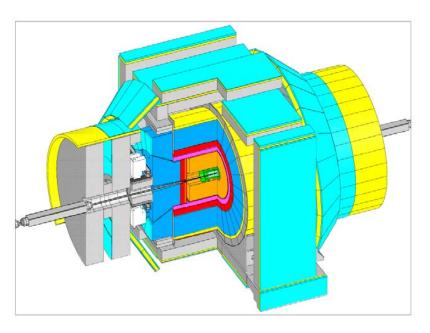
CDF Detector Upgrade





Retained from CDF Run I

- Solenoidal Magnet (1.4 T)
- Central Calorimeter
- Central Muon System



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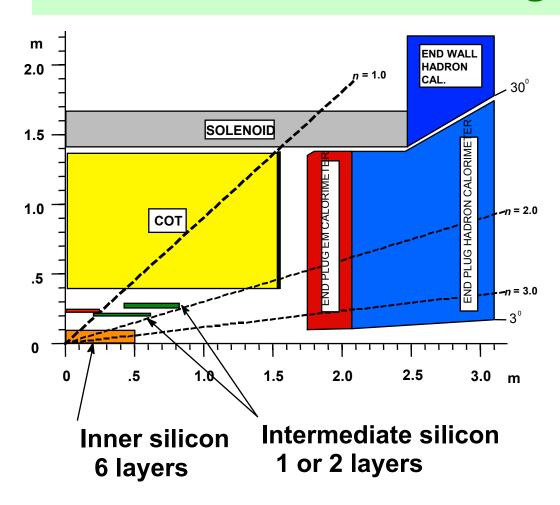
New for CDF in Run II

- Tracking System
 - Central Outer Tracker
 - Silicon Detectors
- End Plug Calorimeter
- Intermediate/Forward Muon Detectors
- Time of Flight System
- Front-End Electronics (132 ns)
- Trigger System(pipelined)
 - XFT (L1): fast 2D COT rec.
 - SVT (L2): select displaced tracks (fast 2D silicon rec.)
- O DAQ

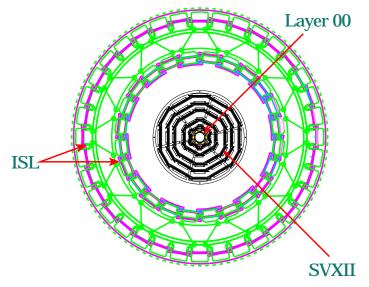
The CDFII Tracking System











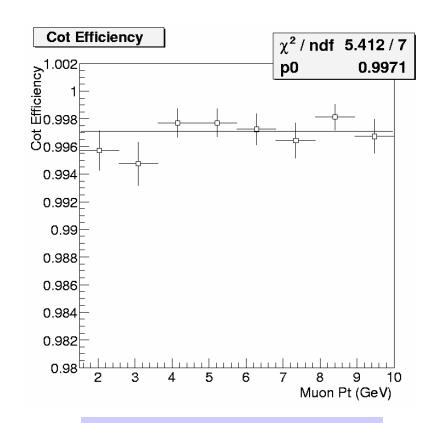
~ 64 cm

CDFII Tracking System - COT





- O Drift Chamber:
 - 8 superlayers (4 axial, 4 stereo)
 - 96 measurements between r=44 and r=132cm
 - All measurements used for dE/dx
 - Tracking for $|\eta| \sim 1.0$
- Extremely Fast Trigger (XFT)
 - Axial Track Trigger
 - 50kHz into Level1 Trigger
 - Full reconstruction at Level 3
- Performances:
 - Tracking efficiency for high p_T isolated W leptons is: $\epsilon = 99.93 \pm 0.21 \text{(stat)} \pm 0.31 \text{(syst)}$
 - $-\Delta p_{T}/p_{T}^{2}=0.15\% GeV/c^{-1}$



COT Tracking efficiency in J/Psi sample (low p_T)

COT Tracking Algorithms



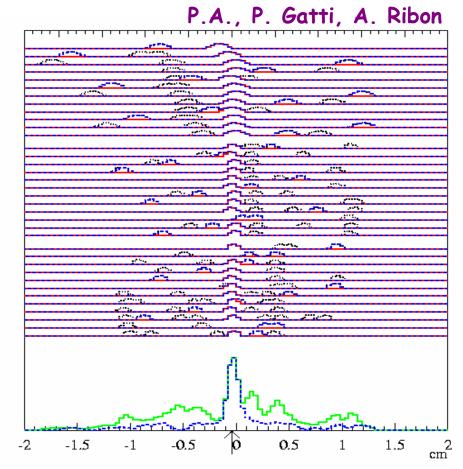


Axial segment linking

- Form segments with hits in axial layers
- Link segments together into tracks

Axial histogram linking

- Start with segment in outer super layers
- Use segment curvature and beamline to form road
- Add hits using histograming method
- Fast method suitable for low mass chamber: minimal multiple scattering
- Complementary to segment linking method
- Followed by stereo segment linking
- Merge tracks from axial methods
 - Two methods help increase efficiency and reduce fake rate(3% gain)



Histogram formed relative to the nominal search path

CDFII Tracking System - Silicon





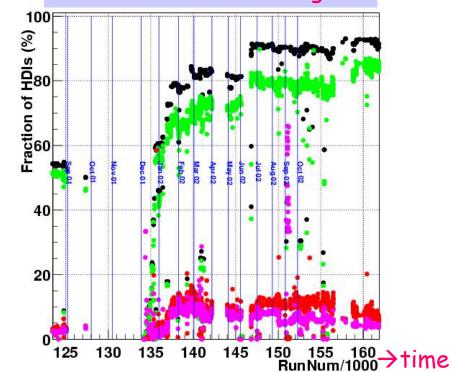
· ISL

- Two layers of double sided silicon (axial, SAS)
- Protects pattern recognition from COT inward
- Allows to extend tracking at large $\boldsymbol{\eta}$

SVXII

- 5 layers of double sided silicon (axial, small and 90° stereo)
- Allows excellent hit and impact parameter resolution

Fraction of Silicon detector active in data taking



● L00

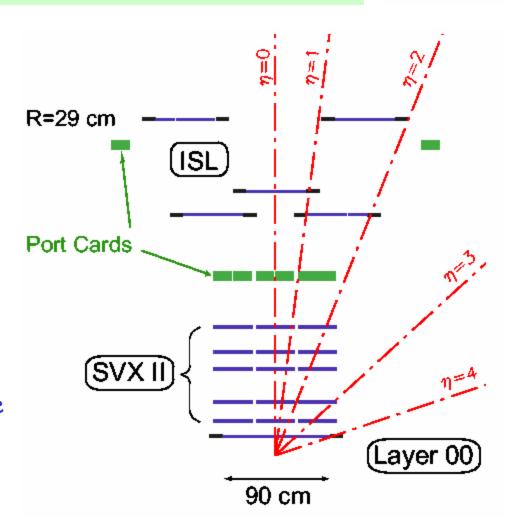
- One layer of single sided silicon, floating strip readout very close to the beamline
- Will provide additional improvement to 2D impact parameter resolution in the hybrids region

Tracking in Silicon Detectors





- Outside-in strategy (central region)
 - COT seeded progressive road search
 - Kalman filter approach used for fit
 - Fast for use at Level 3
- Standalone tracking (large rapidity):
 - Seeded by two 3D measurements on the outer silicon
 - Road is defined between these points and the beamline
 - Progressive road search using same fitter as above

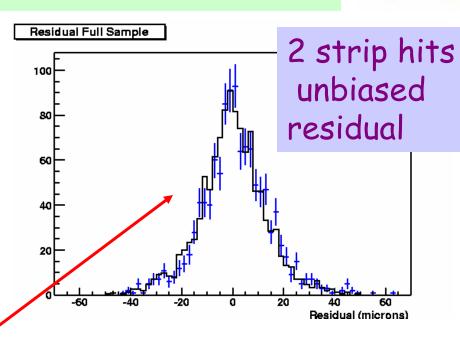


Simulation of Silicon Detectors





- CDFII silicon detector configuration changing in time:
- Accurate simulation essential to be able to reproduce in MC:
 - Hit efficiency and resolution
 - Tracking efficiency and resolution
 - B-Tagging related quantities (data/MC scale factor)
- Latest improvements will be available soon:
 - More sophisticated modeling of the charge deposition
 - · Based on detector intrinsic and operating parameters
 - CDF-Padova main developers: P.A., A. Ribon, M. Menguzzato, R. Rossin



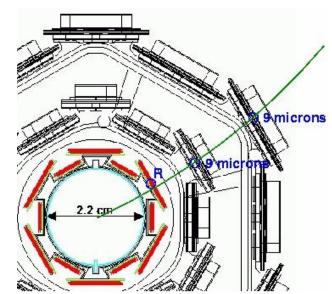
Strip	MC	Data
$\mathbf{W}\mathbf{idth}$	Prediction	Obsertaion
1	13.9 ± 0.7	11.6 ± 0.7
2	8.6 ± 0.2	8.6 ± 0.2
3	12.1 ± 0.5	13.6 ± 0.5
4+	20.0 ± 1.3	21.8 ± 1.1

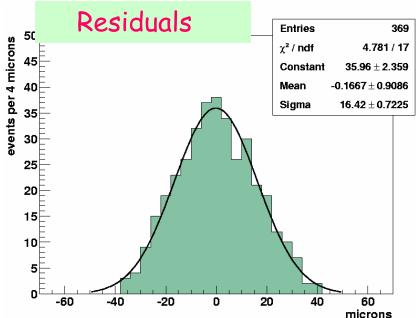
L00 Detector Status





- L00 is >97% integrated into the data taking
 - S/N=10/1
- Techniques developed to cope with the non common-mode noise present in data
 - All channels are read out
- Current focus is on alignment and clustering optimization
- Preliminary results on cluster selection and resolution are encouraging
 - First look at resolution σ =11.2 μ m
 - after subtracting 12µm extrapolation uncertainty
- Studies to include L00 in pattern recognition are in progress!





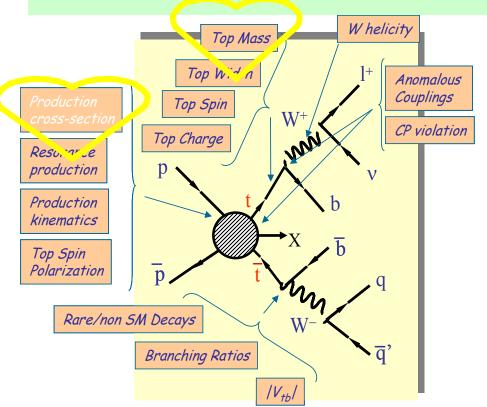


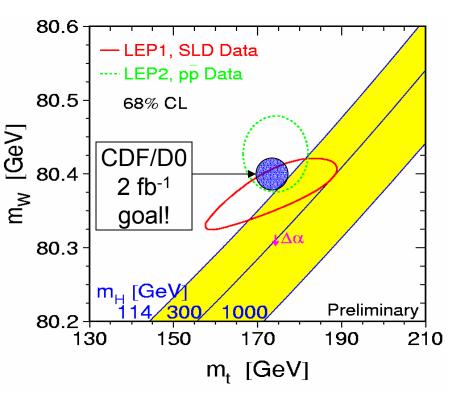
First look at Top physics at CDF in Run II

Top Physics is interesting!









- •Quantum numbers?
- •Production properties?
- ·Decay properties?

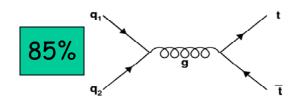
- •Relation to other particles?
- •Is it special?
- ·Clues to new physics?

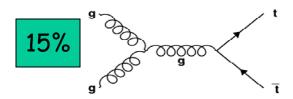
SM Top production & decay at the Tevatron





Top-antitop pair production via strong interaction:

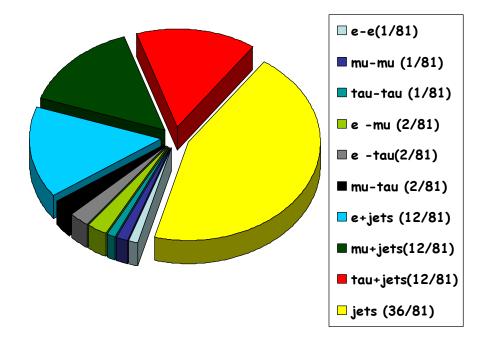




Theory prediction: σ_{tt} = 6.7 pb @ 1.96 TeV (Cacciari et al.)

EW single-top production x2 smaller rate, not yet seen.

 $B(t\rightarrow Wb) = 100\%$, label decays by W modes



$$t\bar{t} \rightarrow \ell \nu b \ell \nu b \Rightarrow dilepton (5\%)$$

$$t\bar{t} \rightarrow \ell \nu bqqb \Rightarrow lepton + jets (30\%)$$

(where I = e, μ)

Dilepton Channel

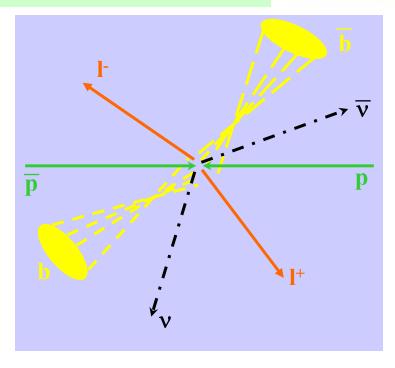




• Event selection (similar to Run I):

- Two high p_T isolated μ or e with opposite charge
- $\Delta\phi(\mathcal{E}_{T}, |/j) > 20^{\circ}$
- Z veto
- E_→25 GeV
- Jets E_{\rightarrow} 10 GeV & $|\eta|$ <2.0
- Use \geq 2 jets for σ_{tt}
- H→200 GeV Total event energy
- $\odot L_{int} = 72 \text{ pb}^{-1}$
- \odot 5 candidates in \geq 2 jets bin
 - 1 ee, 1 μμ , 3 eμ

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Backgrounds

- WW/WZ, $Z\rightarrow \tau\tau$
 - from MC
- Drell-Yan
 - from Data& MC
- Fake leptons
 - From Data

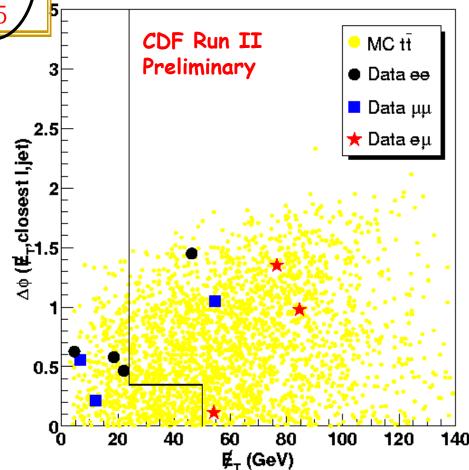
Dilepton Channel Results





<u>Source</u>	<u>æ</u>	<u>μ</u> ι	<u>e</u> u	Ī
Background	0.103±0.056	0.093±0.054	0.100±0.037	0.30±0.12
SMbkg+tt	0.57±0.08	0.68±0.09	1.5±0.2	28±03
Data	1	1	3	5

$$\sigma_{tt} = 13.2 \pm 5.9_{stat} \pm 1.5_{sys}$$
$$\pm 0.8_{lum} \text{ pb}$$



Top Dilepton Candidate Event



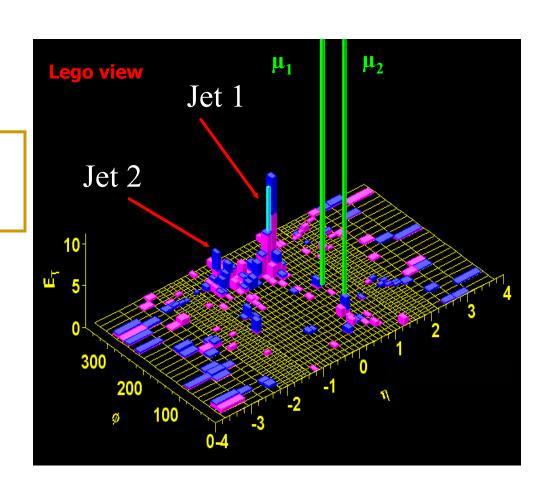


tt dilepton candidate:

Nov 26 2002 run: 154654 event: 7344016

 $\mu^+\mu^-$ (CMUP-CMX) + 2 jets

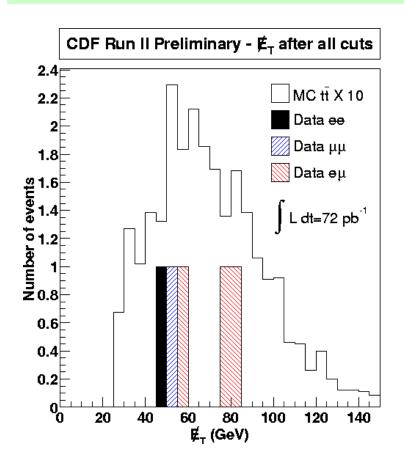
$$p_{T}(\mu_{1}) = 57 \text{ GeV/c}^{2}$$
 $E_{T}^{j} = 32,15 \text{ GeV}$
 $p_{T}(\mu_{2}) = 53 \text{ GeV/c}^{2}$ $F_{T}^{j} = 54 \text{ GeV}$
 $M_{\mu\mu} = 69 \text{ GeV/c}$ $H_{T} = 212 \text{ GeV}$



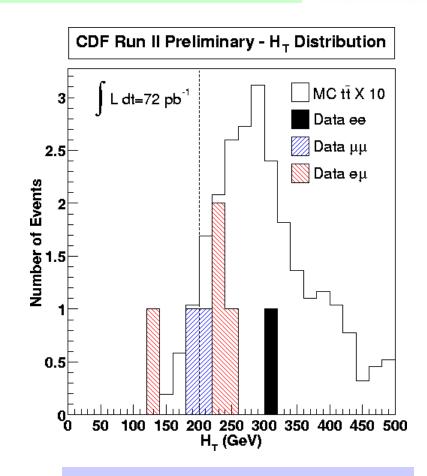
Properties of Dilepton Events







Missing Transverse Energy of candidate events (GeV)



Total Energy of candidate events (GeV)

Lepton+jets Channel



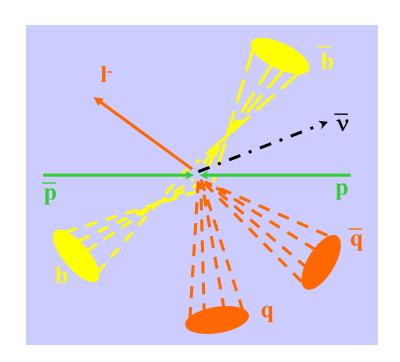


• Event selection (similar to RunI):

- One isolated high p_T central e or μ
- E_→20 GeV
- Jets E_{\uparrow} 15 GeV & $|\eta|$ < 2.0
- Z & cosmic veto
- use W+ \geq 3 jets for σ_{++}

\odot S/B≈1/6 for W+≥ 3 jets: low!

- Signal always has two b-jet (and sometimes a c-jet)
- Only 2% of background has true heavy flavour
- b-tagging improves S/B≈3/1



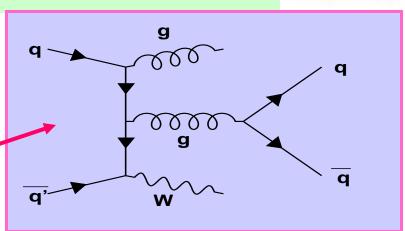
Lepton+jets backgrounds

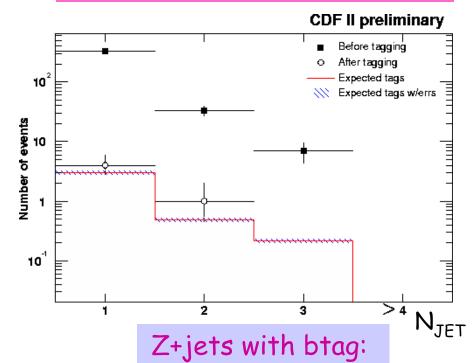




- Reduce background with btagging
 - Secondary Vertex Tagging
- Backgrounds
 - Wbb, Wcc, Wc
 - measured from data and MC
 - Fake tags (from light quarks and gluon jets)
 - measured from data
 - Fake leptons (from QCD bb)
 - · measured from data
 - Diboson, Drell-Yan, single top (small)
 - measured from MC

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calibration channel

Secondary Vertex Tagging



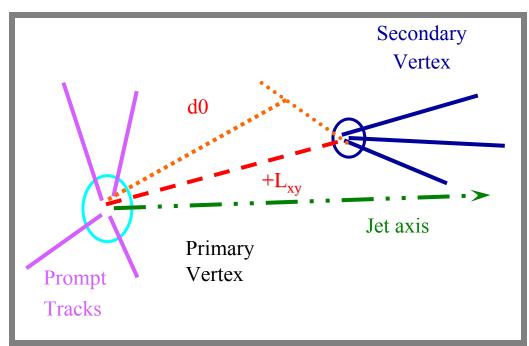


Signature of a b decay is a displaced vertex:

- Long lifetime of b/c hadrons ($c\tau \sim 450 \mu m$)
- B hadrons travel L_{xy} ~3mm before decay with large charged track multiplicity.

·Algorithm:

- Look for displacedvertices: allcombination of at least2 tracks
- Jet is tagged as b-jet if $L_{xy}/\sigma_{xy} > 3$
- typical $\sigma(L_{xy})\sim 150 \mu m$



B-tagging: Efficiency



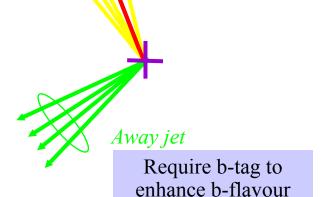
Semi-leptonic b decay



• Jet b-tagging efficiency

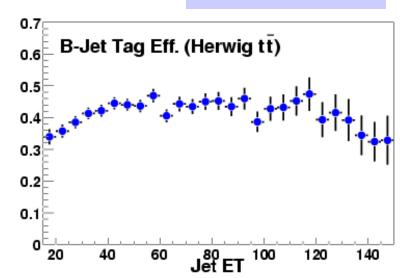
- Measured in inclusive low p_T lepton sample
 - · Rich in heavy flavor
- Measurement in data is compared to bb MC:
 - Determine Scale Factor

ε (Data)	ε (MC)	Scale Factor
0.20±0.01	0.22 ± 0.01	0.89±0.07



Efficiency of b-tagging a tt event

- measure in tt MC (apply SF)
- ϵ (event tag) = 45 \pm 1 \pm 5 %

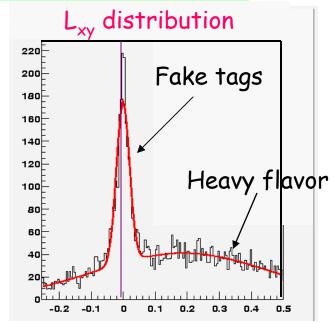


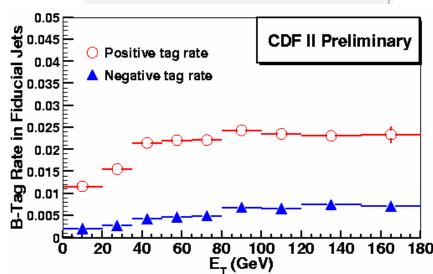
B Tagging: Fakes





- Resolution effects and tracking mistakes are the primary cause for b-tagging light quark or gluon jets
 - L_{xy} distribution has a sign depending on its projection along the jet axis
 - The L_{xy} distribution for fake tags is symmetric around zero
- The fake rate is measured in a sample of inclusive di-jets data
 - Fake tags have: $L_{xy}/\sigma(L_{xy})$ -3



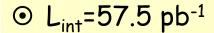


Lepton+jets Backgrounds

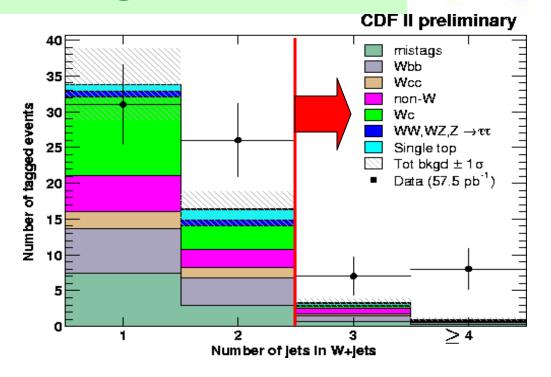




Jet Multiplicity in b-tagged W+jets events



 \odot 15 candidates in \geq 3 jets



Source	W+1jet	W+2jets	W+3jets	W+≥4jets
Background _	33.8±5.0	16.4±2.4	2.9±0.5	0.9±0.2
SM Bkgnd + tt	34.0±5.0	18.7±2.4	7.4±1.4	7.6±2.0
Events before tagging	4913	768	99	<u>26</u>
Events after tagging	31	26	7	8

Lepton+jets Candidate Event



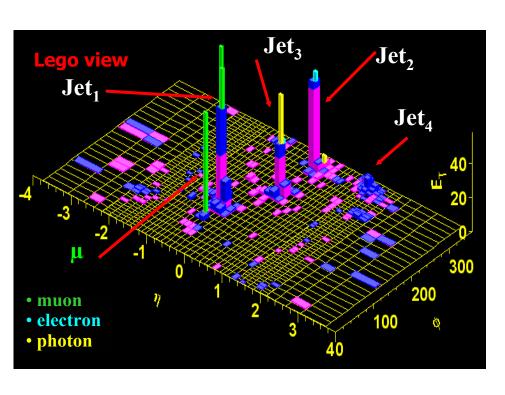


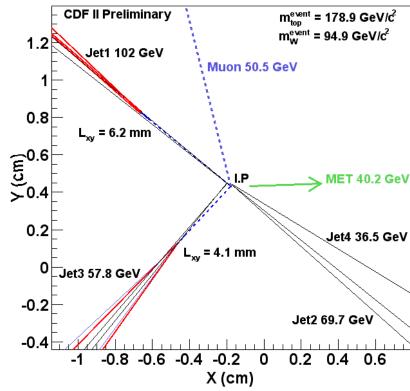
tt l + jet candidate:

Nov 02 2002 run: 153693 event: 799494

 μ (CMUP) + 4 jets



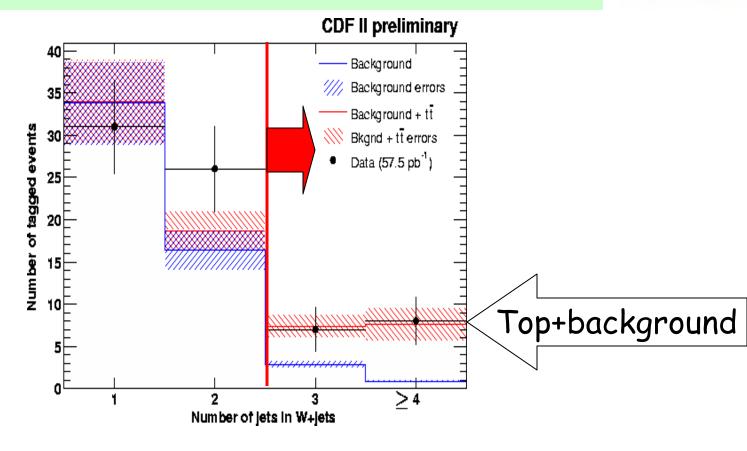




Lepton+jets Channel Results







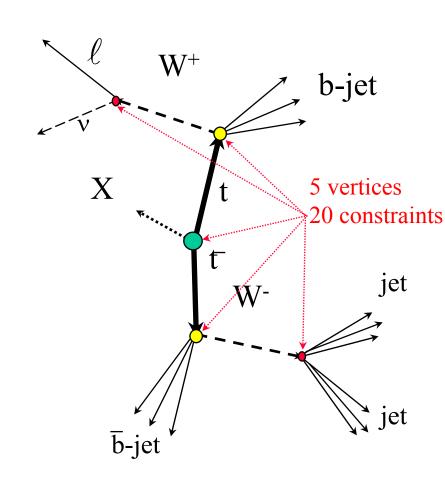
$$\sigma_{tt}$$
 = 5.3 \pm 1.9_{stat} \pm 0.8_{sys} \pm 0.3_{lum} pb

Top Mass: Lepton+jets





- Event Selection similar to cross section analysis, but:
 - Require 4 jet events
 - No b-tag requirement
- Method:
 - 24 combinations
 - 12 correspond to the jetparton match
 - every combination has two solutions for $p_z(v)$
 - Impose energy conservation at each vertex
 - 2-C fit applied, lower χ^2 is chosen for top mass

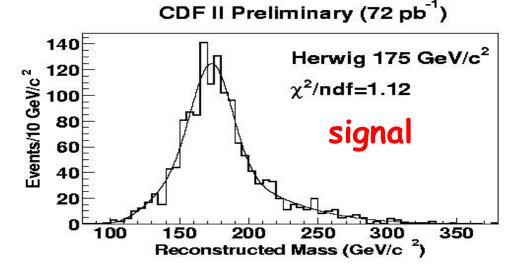


Top Mass Templates

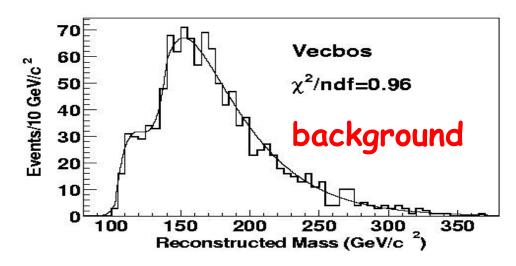




 Reconstructed top masses from data are compared to parameterized templates of top and background Monte Carlo



 Extract top quark mass using maximum Likelihood technique



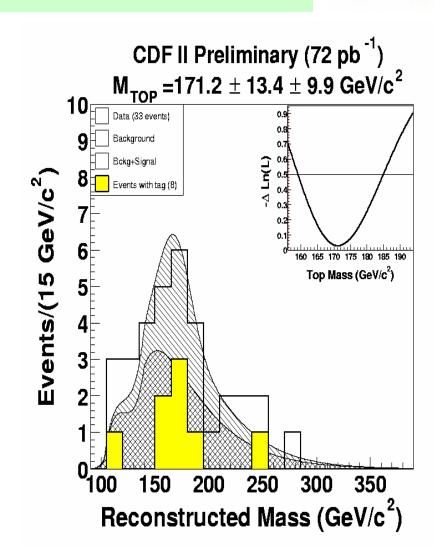
First look at the Top Mass





- ·33 lepton plus 4 jets candidates
- Target jet-energy resolution is 3 GeV for Run 2a.

Source	Uncertainty (GeV/c ²)	
Jet Energy Measurement	9.3	
Initial and Final State Radiation	2.4	
Background Shape	0.3	
Parton Distribution Functions	1.8	
Monte-Carlo Generators	1.8	
Total	9.9	

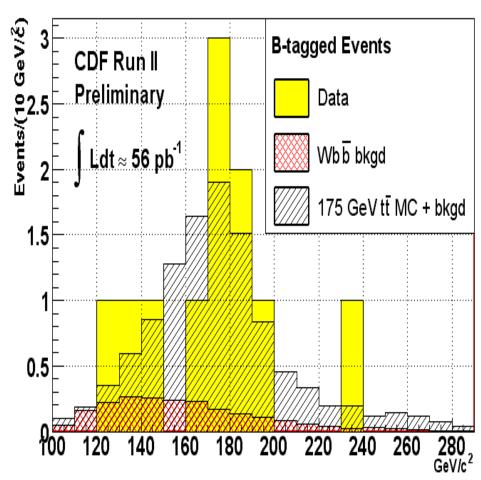


What about using b-tagging?





- Event selection similar to cross section analysis, but:
 - To increase statistics the energy requirement on the 4th jets is lowered to 8 GeV
- The presence of a b-tag:
 - Lowers the background
 - Improves the mass resolution
- Measurement will come soon!



Reconstructed Top Quark Mass, B-tagged Events

Improvement to Top Mass: Z-bb

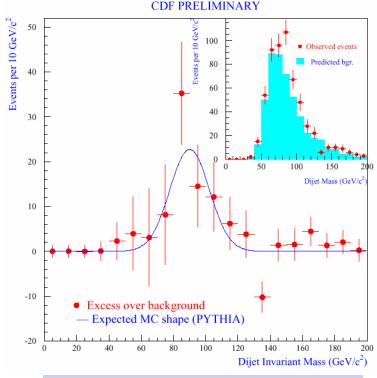




- The goal for Top mass uncertainty in RunII is ~2GeV
- The biggest uncertainty is related to the jet energy scale
- Need to determine corrections/calibration procedures
 - In particular in a top event there are two light quark jets and two b jets
- In RunII the Z→bb signal will allow a calibration of the b jet energy scale from the data themselves
 - $\Box \sigma(Z \rightarrow bb) = 1.2 \text{ nb}$

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Run I $Z\rightarrow$ bb signal (hep-ex/9806022)

-Using low pT inclusive muons sampl

-Not suitable for b energy scale studies

Z-bb Analysis Status

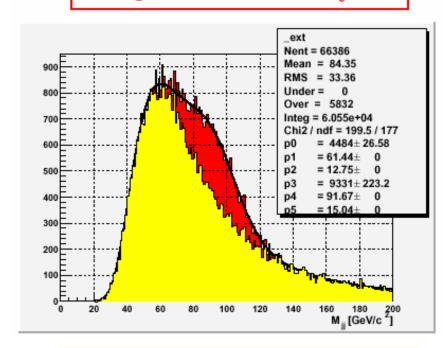




- ⊙ In RunII a dedicated Z→bb trigger is in place based on the SVT information:
 - Two displaced tracks
 - Two jets
 - $\epsilon(signal) = 2.16 \pm 0.007\%$
- Current studies focusing on the L3 trigger selection in order to use a more sophisticated b-tagging algorithm
- Current dataset status:
 - $L_{int} = 30 \text{ pb}^{-1}$
 - Data ~ 670,000 events
 - Signal events expected ~ 350
 - · ...before any analysis cut...

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Projections to $2 fb^{-1}$



Analysis in progress...

Group: Padova INFN(G. Cortiana, T. Dorigo, L. Scodellaro), Harvard U., Chicago U. & LBL

All hadronic channel

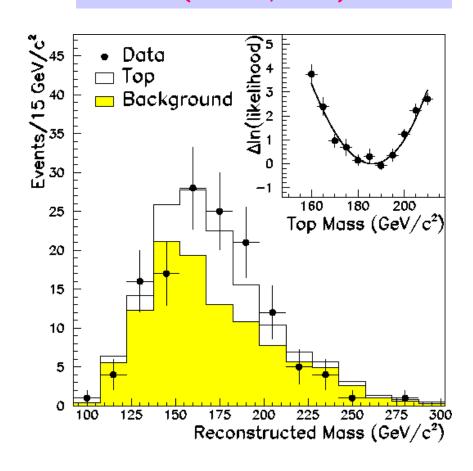




- The all hadronic channel:
 - BR is large (46%)
 - S/B is very small
 - · Need special trigger path
- RunI limitations:
 - Small statistic
 - Small double tag efficiency
 - No MC available for proper background simulation
- RunI analysis strategy was a combination of:
 - A)Tight Kinematic + >= 1 btag
 - B) Loose Kinematic + >= 2 btag
- In RunII we can exploit the full capability of a tight kinematic selection and double tag
 - Achievable 5/B~1/1

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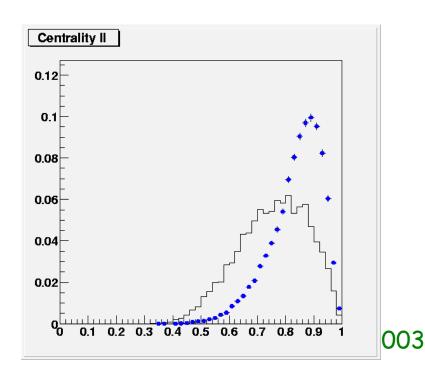
RunI all hadronic channel Top mass (PRL 79, 1997)

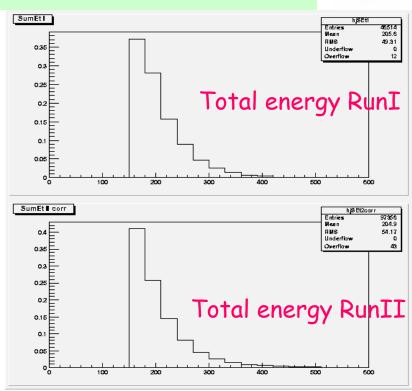


Status of the all hadronic analysis



- Reestablish the baseline analysis wrt RunI
 - Comparison of kinematics properties in data and MC confirms the Run I findings
- Main focus now is on studies of the b-tagging performances in this dataset





Analysis in progress...

Group: Padova (P.A., T. Dorigo), Bologna (A. Castro, A. Gresele), Trento (I. Lazzizzera, S. Amerio)



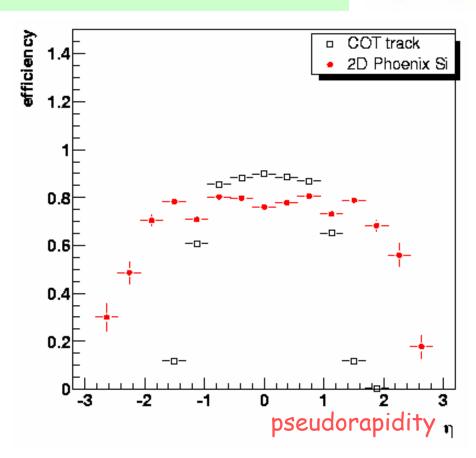
Short and long term prospects for top physics at CDF

Adding forward detector info





- Increase the efficiency for top events looking at large eta
- Forward electrons
 - Dedicated tracking algorithm
 - Double the acceptance for top dilepton
- Forward muons
 - Dedicated trigger under development
- Forward b-tagging
 - Extend b-tagging up to $|\eta|^2$



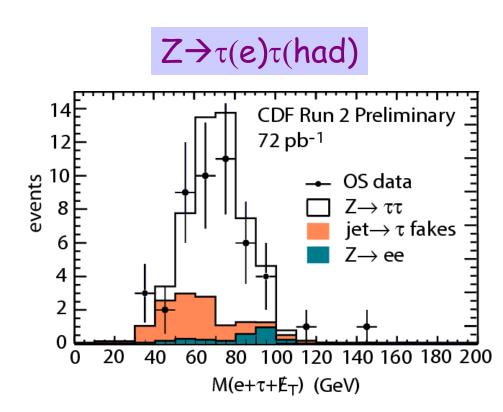
Efficiency for forward electron tracking (red) compared to COT only (black)

Adding the tau channels





- Complete the observation of a top signal also in the following finale states:
 - Dilepton: e,mu+tau(hadronic)
 - · Ready soon!
 - Tau(hadronic)+jets
 - · More challenging...
- Hadronic tau identification algorithm in Run II performs well in EWK signals:
 - W $\rightarrow \tau_{had} v_{\tau}$ cross section
 - $Z \rightarrow \tau_{lep} \tau_{had}$ cross section
- Ready to be used in top physics!



Top Physics reach in RunII





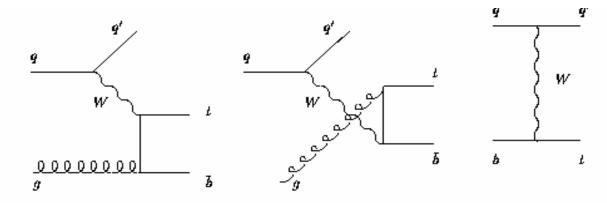
Measurement	2fb ⁻¹	15fb ⁻¹	Comment
Yields			
N _{4jet*2b}	250	1800	Clean mass sample
δ m(top)	3 GeV/c ²	2 GeV/c²	Total precision
Production			
$\delta\sigma_{tt}$	9%	6%	Test top QCD coupling
δσ ₊₊ /σ _{I+j}	12%	9%	Test nonW decays
Decay			
$\delta B(t \rightarrow W(b))$	3%	1%	From N(bb)/N(bX)
δ B(†→(W)b)	9%	3%	From N(II)/N(IX)
$\delta B(W_{V+A})$	3%	1%	W helicity
δV_{tb}	26%	6%	From above
Rare Decays			
Β(cγ)	≤ 3×10 ⁻³	≤1×10 ⁻³	@95% <i>C</i> .L.
B(cZ)	≤ 1.3×10 ⁻²	≤ 5×10 ⁻³	@95% <i>C</i> .L.

Single Top physics in RunII





- Single top physics: all new!
 - \odot Production cross section about $\frac{1}{2}$ of tt
 - Single top samples less clean



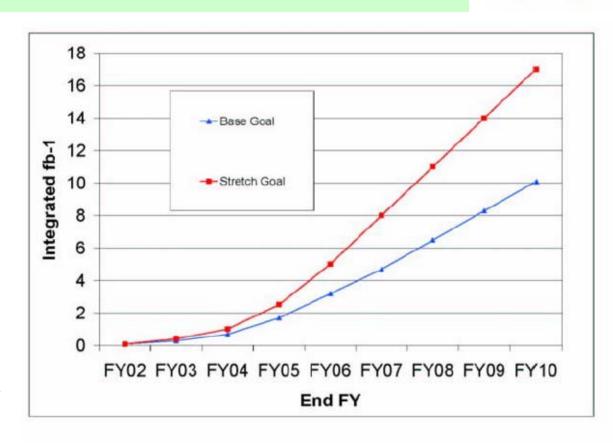
Data	1fb ⁻¹	10 fb ⁻¹
$\delta\sigma(tbX)$	26%	10%
$\delta\Gamma(t\rightarrow Wb)$	28%	12%
$\delta V_{tb} $	14%	6 %

Future Accelerator Prospects





- ⊙ 350 pb-1 delivered by Sept 2003
- Between 6.5(baseline)
 and 11 fb-1 (streched)
 delivered by 2008
- Shut down (~8 months) for installation of RunIIb upgrades in Spring 2006
 - ⊙ 396 ns interbunch is new baseline value



- -Peak luminosity 4x10³² cm⁻¹s⁻¹
- -Large number or multiple interactions per crossing!

Run2B Detector Upgrades





Silicon Detector:

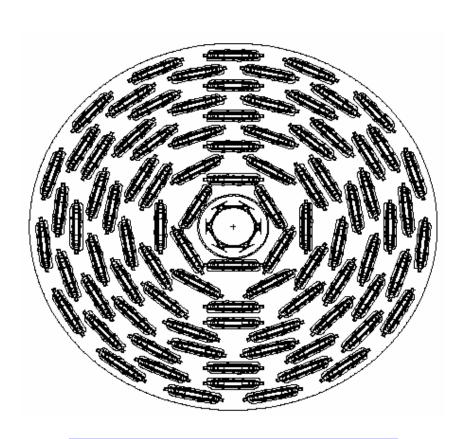
- 6-fold symmetry
- 1 stave design for all 5 outer layers
- Fill all space available up to ISI.
- Innermost layer (LO) similar to the present LOO

• Calorimeter

- EM timing information added
- CPR Replacement

⊙ DAQ:

- Level 2 Trigger Upgrade
- 3D XFT (stereo info)
- SVT upgrade



Run2b Silicon Layout

High Luminosity Physics Issues

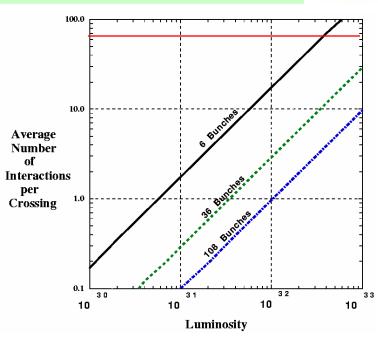


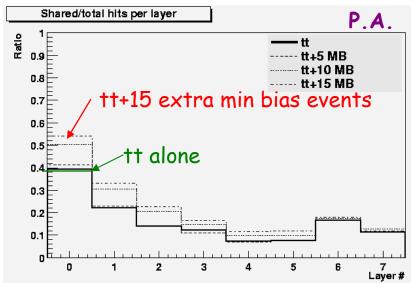


 Large number of interactions for beam crossing: effects on tracking and physics performances.

 Effects on tracking and b-tag performances in top events as a function of extra multiple interactions have been studied







Conclusions





- The Tevatron Run II data taking is well underway
- Using datasets between 57 and 70 pb⁻¹ CDFII has been able to reestablish the observation of Top quark with properties consistent with the Run I discovery
- Next, CDF will use all the improvement of the upgraded detector to increase signal acceptance and background rejection (more channel, higher efficiencies, lower fake rates...)
- The time for precision Top physics results is getting near!